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An investigation of mandibular asymmetry and associated soft-tissue characteristics among adults: A digitalized orthopantomographic and photographs assessment

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ABSTRACT

Introduction: There are many controversies behind the topic of mandibular asymmetry. Conflicts include: gender predilection, soft tissue correlation and what is considered normal asymmetry. Consequently, this study was done to investigate the prevalence and severity of mandibular asymmetry among adults in a sample from orthodontic clinics and to assess the soft tissue correlation and gender predilection. *Methods:* Mandibular asymmetry was investigated on a standardized digitalized orthopantomograms of 793 adults attending Riyadh Elm University, orthodontic clinic following strict eligibility criteria. This study started in July 2020 to October 2021. Asymmetry index (AI) used to analyze the prevalence and gender incidence. Soft tissue assessment for 87 of the mandibular asymmetric participants was done on a standardized photograph checking the soft tissue correlation measuring the area, perimeter and compactness for the two sides of the lower third of the face. The resulted ratios correlated with (AI). Both radiographic and photographic assessment was done on AutoCAD LT 2021 software (version R.46.M.1748). *Results:* Considering participants of 3% or greater in Asymmetry Index (AI) as asymmetric. Therefore; 20.9% of males' subjects represent mandibular asymmetry, while the incidence in females was only 13.69%. Moreover, there's no significant link between hard and soft tissue asymmetry, the correlation (r) between Asymmetric index (AI) and area ratio (AR) was recorded as .062 indicating a weak positive relationship. *Conclusion:* Ultimately, it can be concluded that soft tissue is not associated with hard tissue asymmetry. Moreover, Radiographic based mandibular asymmetry showed high prevalence rate in both adult genders with higher incidence in males.

Keywords: Mandibular, Asymmetry, Soft-Tissue, Assessment, Orthopantomography.

1. INTRODUCTION

Nowadays the importance level of aesthetic and facial features has reached to seeking perfectionism, people admire balanced features, symmetrical faces, and proportionate facial structure (Faure et al., 2002). Science in orthodontics and anthropometry has guided surgeons towards achieving their patient's proportionate features by determining the complete comprehensive facial analysis method (Bueller, 2018). Orthodontics developed symmetry diagnosing methods and standard facial analysis; dividing the face into horizontal fifths and vertical thirds which ideally should be equal (Bueller, 2018). Asymmetry is found in all anatomical structures, more often in the lower third of the face, due to the prolonged growth of the mandible (Haraguchi et al., 2002). It would be either due to hard and\or soft tissue imbalance. Hence the soft tissue asymmetry could be correlated to the underline hard tissue structure or independent from it, It might even compensate for the hard tissue asymmetry (Siqueira de Lima et al., 2019). The etiology for the asymmetry in the lower third of the face is categorized as developmental, acquired, pathological and functional depending on its etiology (Cheong & Lo, 2011; Chia et al., 2008).

Furthermore, there are multiple aspects for diagnosing skeletal asymmetry, particularly of the lower facial third. In pathological asymmetry, biopsies are usually required. Radiographic and photographic assessment can be done depending on the case (Chia et al., 2008). As for the soft tissue assessment, photographic mandible tracing found to be reliable, in form of measuring the area, perimeter as well as compactness (Greenhill et al., 2000). Asymmetry index (AI) by (HABETS et al., 1988) is used to measure the vertical asymmetry of the mandible on an orthopantomogram radiograph, which can be considered one of the best choices in this demand as it is reliable enough and it produces less radiation compared to CBCT (Habets et al., 1988).

Masuoka et al., (2005) stated that there is no correlation between soft tissue and skeletal asymmetry. However, a study by Young et al., (2016) reports that soft and skeletal tissues are significantly correlated. Correlation analysis studies were made on 3-dimensional radiographs, and to this date, there isn't a study that investigates the asymmetry index (AI) and correlates that with photographic assessments. Associating both radiographic and photographic assessment methods simultaneously is necessary hence asymmetry index is done exclusively on orthopantomogram.

Unfortunately, that's not the only controversy behind the topic. It hasn't been agreed on what is considered normal asymmetry by craniofacial orthodontics (Lee et al., 2010; Melnik, 1992). Furthermore, there are disagreements in the literature on whether there is a gender predilection (Ferrario et al., 2001; McCrea & Troy, 2018). Accordingly, the current study is conducted to investigate the prevalence of mandibular asymmetry among adults in a sample from orthodontic clinics, and, assess the soft tissue correlation and gender predilection if present.

A null hypothesis has been stated as "no statistically significant differences would be existing between the average values of bilateral mandibular measurements of asymmetry among both genders from the selected subjects nor between their skeletal and soft tissue dimensions comparison when the level of significance used to be $P < 0.05$".

2. MATERIALS AND METHODS

This study started in July 2020 to October 2021 and has been done on two steps. First step was to analyze Orthopantomogram records of adults who attend orthodontic clinics at Riyadh Elm University (REU) campuses, Riyadh, Saudi Arabia. An identification of the significant skeletal asymmetry has been conducted, which result as a 3% with the asymmetry index (AI) (Habets et al., 1988; McCrea & Troy, 2018). Second step, analyzing of the selected photographic records was performed. However, analyses have been done only on patients with confirmed skeletal asymmetry with significant (AI).

Initially, the sample size has been calculated and described by formulas which ultimately showed to be 315 orthopantomogram records are required, yielding to avoid a 5% margin of error. But during the data collection the sample size has been reached 900 orthopantomogram records. Photographic record collection was done dependent on the presence of significant mandibular asymmetry in the radiographic investigation stage.

An inter-investigator's reliability was determined as a pilot study among same 10 orthopantomograms as well as 10 photographs interpretation using computing Cohen's Kappa test and score of K=0.884 has been achieved, which indicated adequate reliability between the chosen three investigators who perform all measurements subsequently. One particular investigator (First Author) was assessing the accuracy of used software, the methodological quality of the radiographs, and photographs interpretations independently. The selected radiographs for the pilot study have not been included in the final study sample.

Step I: Radiographic Investigation

Data Collection

A standardized 793 orthopantomogram records has been collected from REU's clinics as all were taken by the same machine using same settings with: 2D Sirona dental device system (Orthophos XG 5, SW-version: V2.41.01, HW- version: BB, benshiem, Germany) radiation wavelength 50/60 Hz, 200 -240 V, Model-No: D3352, Serial-NO: 85570, max 12A. Sample was collected following strict eligibility criteria as described in (Table 1 and Figure 1).

Table 1 Orthopantomogram Eligibility criteria

Inclusion criteria	Adults, (16yrs-48yrs). The entire mandible must be fully apprehended with no positioning distortion on the radiograph.
Exclusion criteria	History of facial trauma. Syndromes related to the oral maxillofacial region. Pathology lowers facial third. Condylar resorption (TMD) problems. History of orthognathic surgery

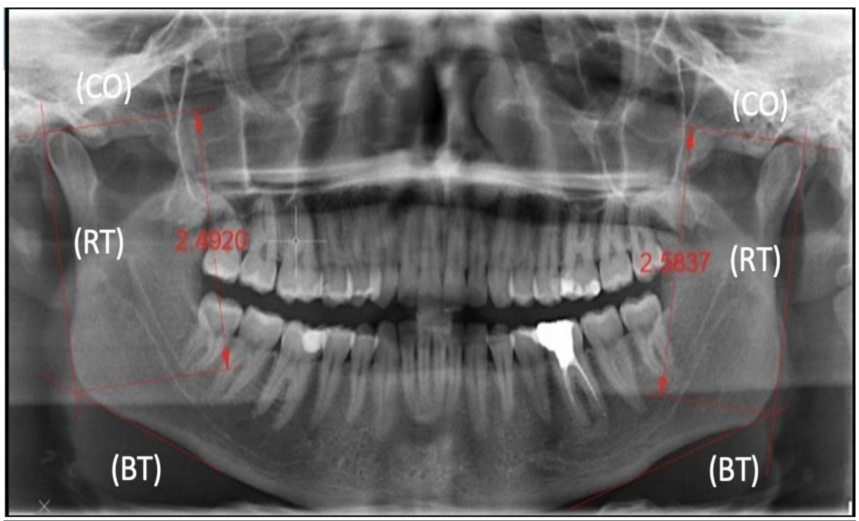

Figure 1 Orthopantomogram interpretation

AutoCAD LT 2021 software (version R.46.M.1748) by Marin Software Partners Company with same setup settings (Table 2) was used to analyze the orthopantomogram radiograph by establishing specific linear measurements (Table 3).

Table 2 Standardized settings used in AutoCAD LT software

Sittings	Definition
Length unit	Inches
Precision of the length	0.0000
Angles unit	Decimal degree
Precision of the angle	0.000
The insertion scale unit is in Millimeters with a drawing scale ratio	1:1

Table 3 RT; Ramus tangent line. BT; Body of the mandible tangent line CO; condylar head tangent line

Point	Definition
(RT) (BT) (CO)	The tangential line at the posterior border of the mandibular ramus The tangential line at the body of the mandible. Tangent line at the highest point of the condyle which is perpendicular on RT
intersection line	Intersection line set up the lower reference point. Intersection line set up the upper reference point.
RT and BT CO and RT	

The orthopantomogram radiograph analyzed with specific linear measurements by first drawing a line tangent to the most lateral point of the mandibular ramus (RT) which intersected with two drawn lines:
Tangent line to the body of the mandible (BT)
Tangent line at the highest point of the condyle (CO) which is perpendicular on the ramus line (RT)

The bilateral distance between the two intersection points has been measured and used for calculating the severity between heights of both mandible rami (AI)

$$\boldsymbol{Asymmetry\ index\ (AI)} = \frac{\text{left R} - \text{right R}}{\text{R} + \text{right}} X\ 100\ \text{left}$$

Step II Photographic Assessment

Data Collection

Photographic records were collected from REU's orthodontic clinics, as it is part of the routine diagnostic records taken for each particular patient following an additional strict eligibility criterion (Table 4). The camera settings were standardized and uniformly set using digital SLR Canon EOS 750D with manual mood, Shutter Speed: 1/250 or faster, Aperture: Wide open (f/1.4-f/2.8), ISO: as high as possible; 3200 max and a focal length of 1 meter. The patient's backgrounds were all unified and raw image quality, simple lens (EF-S 18-55mm), as well as ring flash, has been used. The patient's confidentiality has been strictly monitored and considered.

Table 4 Photographs eligibility criteria

Inclusion criteria	Clear photograph with the same standardized setting. Patients on natural head position. Patient represent ≥3% mandibular symmetry index (AI) Signed consent
Exclusion criteria	Covered ears History of injectable facial fillers History of facial plastic surgery Beard covering the mandible natural outline

Photographic interpretation

AutoCAD LT 2021 software was used again for photographic assessment by the same investigators. Soft-tissue assessment was conducted by analyzing the area, perimeter, and compactness following certain formed linear measurements (Table 5 and Figure 2).

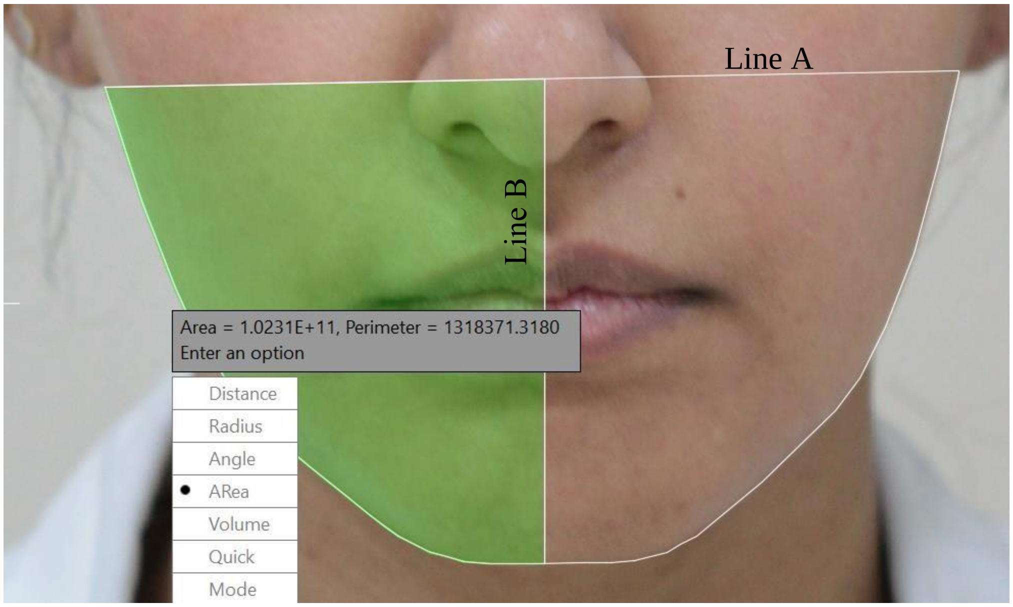

Figure 2 Photographs assessment.

Table 5 Photographs assessment

Line name	Definition
Line A	A line at the most inferior insertion of the ears.
Line B	A line at the midpoint and perpendicular to line A.
An outline	Outlining the mandible.

The assessment was done by drawing three lines as shown in (Table 5). First drawing a line at the most inferior insertion of the ears, called line A, the line then would be trimmed to have the edges of the line precisely on the facial outline. Line B then would be drawn which is at the midpoint and perpendicular to line A, dividing the face into right and left. Lastly, facial outline is then drawn using autocade feature called polyline which helps with the curvature of the face. The analysis divided the lower third of the face into two segments at the midline plane. Area and perimeter of the two sides were measured. Then area and perimeter ratio and compactness are calculated with:

$$\textbf{Area ratio} = \frac{\text{left A} - \text{right A}}{\text{left A} + \text{right A}} X\ 100$$

$$\textbf{Perimeter ratio} = \frac{\text{left P} - \text{right P}}{\text{P} + \text{right P}} X\ 100 \text{ left}$$

$$\textbf{Compactness} = \frac{P2}{4\pi A} X\ 100$$

P: perimeter

A: area

3. RESULTS

The study was conducted to investigate the severity of mandibular asymmetry among adults in a sample from orthodontic clinics, and to assess the soft tissue correlation and gender predilection if present. For this purpose, both descriptive statistics (mean,

standard deviation, frequency and percentages) and inferential statistics (Independent t test and Pearson correlation coefficient) were computed to test the variables of the study. Sample size was conducted to be 315. However, (963) orthopantomogram records were collected to fulfill the needed requirements and to avoid any limitations and shortage in data and to have proper correlation with enough sample size of soft and hard tissue records. After radiographic eligibility criteria it resulted with 793 records. 123 of the records was excluded because radiographic distortions. 38 were excluded due to having old records that has been taken in early adolescence or childhood. 5 were above the age range, 2 were because of the history of orthognathic surgery and 1 has been diagnosed with condylar resorption, 1 due to history of condylar fracture.

Overall, 793 study participants were recruited for the study. Total asymmetry group out of the sample were 131. The photographs collected were 87 after applying the eligibility criteria, excluding 19 of them for not wanting to participate in this study, 12 of them for not having their facial outline clear, due to having a beard or wearing a hijab, 2 of them for having facial fillers or history of plastic surgery. All data variables were analyzed with SPSS software (version 21). Findings from the study analysis were presented in Tables and Charts. P-value ≥ 0.05 ($P \leq 0.05$) was deemed statistically significant.

Distribution on gender and age among the study participants

Findings from the study analysis revealed that, majority of the study participants were females. This group were represented by 60.8% representing 482 of the respondents whilst the remaining 311(39.2%) were males. Participant's average age was recorded as 23.92 ± 7.54 years, with a documented minimum and maximum age of 16 years and 48 years respectively. Distribution on age and gender among the participants is presented in (Table 6 and Figure 3) respectively.

Table 6 Distribution on age among the study subjects

Variable	Mean ± SD	Minimum	Maximum
Age/years	23.70 ± 6.99	16	48

N = 793

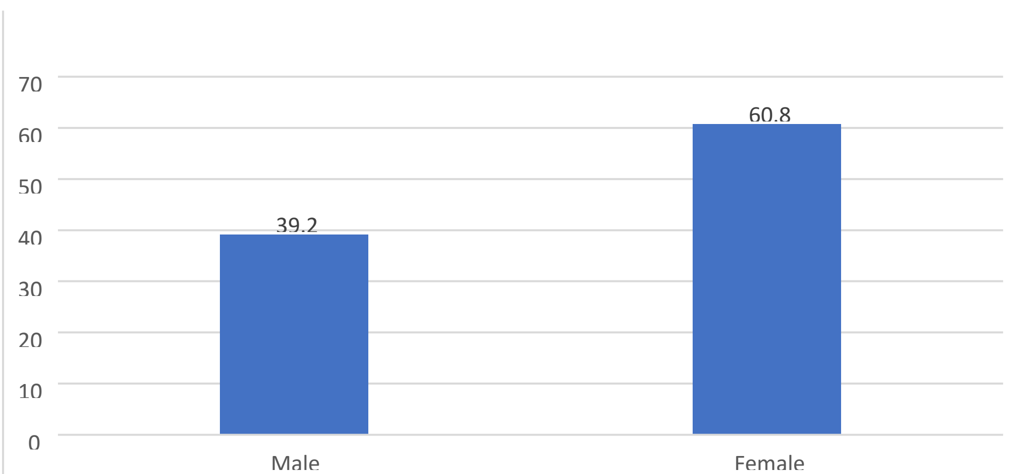

Figure 3 Distribution on gender of study participants

Correlation between radiographic assessment and photographic assessment

Pearson Product Moment Correlation Coefficient was computed to test the linear relationship between radiographic and photographic assessment (Area ratio, perimeter ratio, and compactness ratio). The correlation (r) between Asymmetric index (AI) and area ratio (AR) was recorded as .062 indicating a weak positive relationship between asymmetric index and area ratio. The correlation between asymmetric index and perimeter ratio was documented as -.050 whilst the relationship between asymmetric index and compactness ratio was noted as -.096. These represent a very weak negative correlation between radiographic assessment and photographic assessment. The correlation distribution is presented in (Table 7).

Table 7 Correlation between radiographic and photographic assessment

	AI
AR	.062
PR	-.050
CR	-.096

**Correlation is significant at the 0.05 level; AI: Asymmetric index, AR: Area ratio, PR: Perimeter ratio, CR: Compactness ratio*

Percentage incidence of prevalence and severity of mandibular asymmetry among the study subjects

The percentage incidence of prevalence of mandibular asymmetry among the study subjects was explored and presented in (Table 8 and Table 9). Findings from the study analysis indicated that, there existed a significance difference in prevalence of mandibular ramal asymmetry (PMA) among genders that is more males (20.9%) than females (13.69%) represented asymmetry exceeding 3% of AI presented in (Table 10).

Table 8 Prevalence and severity of mandibular asymmetry incidence among the study subjects

	AI VALUE		
	Male, 311	Both gender, 793 (137)	Female, 482
Prevalence PMA (%)	21.5%	17.3%	14.5%
Average Total AI	1.9	1.77	1.69
Average of IA among asymmetry group	4.227	4.37	4.5
Severity	19.62%	25.2%	31%
Right side dominance	50.8%	55.1%	57%

Table 9 describing the distribution of participants and incidence of mandibular asymmetry 793 participants were recruited for the study

Gender	presented with mandibular asymmetry in number	presented with mandibular asymmetry in %
Male	311	21.5%
Female	482	14.5%

Table 10 Paired Samples T-Test [Females]

Paired Samples T-Test Females	N	Mean	Median	SD	SE
Right side ramus	482	2.46	2.46	0.206	0.00940
Left side ramus	482	2.44	2.44	0.207	0.00941

Table 11 Paired Samples T-Test [Males]

Paired Samples T-Test Males	N	Mean	Median	SD	SE
Right side ramus	311	2.71	2.70	0.247	0.0140
Left side ramus	311	2.70	2.71	0.256	0.0145

4. DISCUSSION

In determining facial asymmetry, it is known that deviations in the mandible are the most striking characteristic of the discrepancy, especially the chin's lateral displacement in regard to the midsagittal plane (Masuoka et al., 2007). Mandibular asymmetry (MA) is common in those who have had a craniofacial injury, syndrome, or other ailment. However, research into the variables that cause idiopathic asymmetry, which occurs without the presence of other disorders or congenital abnormalities, is scarce (Bailey et al., 2001). There are few epidemiological data on these asymmetries in the literature. Few authors have investigated MA specifically and evaluated associated factors with large samples, and those studies did not demonstrate how substantial the associations were (Thiesen et al., 2015).

The topic of mandibular asymmetry is quite broad with many factors having some sort of effect on it, quantitative measurement of the mandible asymmetry is done with both 2D and 3D radiographs; Previous studies have proposed that panoramic radiography is suitable for measurement of the height of the condyle and the overall height of the frame when the goal is to account for the size difference between the right and left mandibles. Changing the head position does not affect vertical dimensions, but horizontal dimensions are affected. With the asymmetry index only measures the vertical height, the 3d radiographs assessment is surely more accurate. However, the fact that in some centers CBCT is taken when the patient is in the supine position which can have the face affected by gravity (Athanasiou et al., 1989).

In a study conducted by Habets et al., (1988), he stated that when a 6% vertical panoramic radiograph's right and left sides are different should be noted as unusual and regarded as sign of asymmetry. Gender predominance in mandibular asymmetry is a controversial topic, many previous results on this regard were not consistent (Thiesen et al., 2018). It could be because it is a multifactorial issue and with the difficulty of standardization of numerous aspects as age, habits, race, etc. Our findings show an asymmetry is extremely common in adults of both sexes, with males having the highest occurrence. In this regard, McCrea et al., (2018) who aimed to assess the prevalence and severity of mandibular asymmetry, identify gender differences, and assess lateral prevalence. using mandibular asymmetry index also stated that males (23.9%) had more incidence of ramus mandibular asymmetry than females (12.5%). Age plays a major role in asymmetry, especially in the mandible, since it has a late growth cessation (Subramaniam & Naidu, 2010). During growth spurts, sex hormones of each gender have different effects on skeletal growth.

Although the current study followed strict eligibility criteria for its subjects, other factors associated with soft tissue asymmetry were not included such as masticatory habits, sleeping habits, and smoking, all of which can cause soft tissue asymmetry which is independent of the skeletal growth. Studies showed a positive correlation of the thickness of masticatory muscles with both horizontal and vertical dimensions of the mandible (Kim & Kim, 2020). Sleeping habits can be a confounding factor when studying MA as sleeping more frequently on a specific side since an early stage in life can also cause craniofacial asymmetry (Iyer et al., 2021). The link between hard and soft tissue characteristics varies because some soft tissue features are intimately tied to hard tissue whereas others are influenced by their length and function (Kasai, 1998). A previous study that had 2-dimensional data, focusing on the soft-tissue profile outline with traditional cephalometric found that soft-tissue shape was correlated to skeletal shape by a coefficient of determination of approximately 50% (it means that skeletal shape was responsible for half the changes seen in soft-tissue shape) (Halazonetis, 2007).

These findings are comparable to a study that performed correlation analysis studies on 3-dimensional CBCT radiographs and reported that soft and skeletal tissues are significantly correlated (Choi et al., 2013). Both these findings come in conflict with the present results. On the other hand, Masuoka et al., (2005) stated that there is no correlation between soft tissue and skeletal asymmetry. Others suggested that soft tissue compensates for the hard tissue asymmetry, suggesting that thicker layers have a higher rate of compensating for the asymmetry (Burstone, 1998; Vargas et al., 2020). Our results also showed no significant correlation among both hard and soft tissue, which is supported by these previous findings. Thus; the null hypothesis is accepted.

5. CONCLUSION AND RECOMMENDATION

Within the limitation of the current study, it can be concluded that: Mandibular ramus asymmetry showed to be highly prevalent, male showed higher incidence, thus; showed a gender predilection and there was no hard tissue and soft tissue correlation. Studies aiming find whether or not a correlate among both hard and soft tissue exists should be done with specific age group and as the genders as two different groups, using 3D photographic imaging for investigation as well as CBCT is recommended for more accurate results and correlation while taking participants chewing habits into consideration.

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Authors Contribution

Nancy Ajwa - Principal Investigator, Study design, Manuscript Preparation.

Nora Ababtain, Daniyah Alsulaiman, Shahad Alotaibi, Maram Alqahtani, Khames T. Alzahrani- Co-Investigators, Study design, Data collection, Statistical analysis, Manuscript Preparation.

Ethics approval consideration

Institutional research ethics board approval was acquired before conducting any study-related procedures. Ethical approval was obtained from Research Ethics Committee Riyadh Elm University (REU) with the IRB approval number (FUGRP/2020/187/261/262).

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Conflict of Interest

The authors declare that there are no conflicts of interests.

Data and materials availability

All data associated with this study are presented in the paper.

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